Contralateral Effects of Upper Extremity Proprioceptive Neuromuscular Facilitation Patterns

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Electromyography was used to determine the presence of electrical activity in the nonexercised latissimus dorsi, infraspinatus, and pectoralis major muscles while the contralateral limb underwent the proprioceptive neuromuscular facilitation pattern of flexion, abduction, external rotation with elbow straight and extension, adduction, internal rotation with elbow straight. Activity was present in all of these muscles during both components of the pattern. There was no significant difference in activity for the pectoralis major muscle during the flexor as compared to extensor component. The infraspinatus was more active during the flexor component, while the latissimus dorsi was more active during the extensor component. These results could be used in planning a treatment program for patients who are unable to exercise one of their upper extremities and who could benefit from the contralateral effects of upper extremity proprioceptive neuromuscular facilitation patterns.

Key Words: Electromyography, Exercise testing, Physical therapy.

Proprioceptive neuromuscular facilitation (PNF) techniques are widely used in therapeutic exercise programs. One of the contentions of the proponents of PNF is that it can cause a contraction of muscles in the contralateral extremity during unilateral exercise. Patients with burns, fractures, or arthritis may be unable to exercise the involved limb and would benefit from the indirect approach of exercising the noninvolved limb in order to obtain contralateral muscle activity. To set up an adequate treatment program, the physical therapist should know how optimally to affect the weakened muscles in the nonexercised extremity. The PNF approach to therapeutic exercise suggests that the overflow effects would be in the inadequate muscular pattern. However, experimental evidence of what that inadequate pattern is, is lacking.

The literature has revealed two possible explanations for patterns of contralateral effects. One theory is based on the overflow of impulses from the muscles that are directly being exercised. The impulses are thought to be directed to muscles corresponding to the agonists or antagonists of the limb undergoing resisted exercise. The other theory is based on biomechanics: the effects are due to stabilization of the contralateral side when resistance is applied to the exercised limb. Kruse and Matthews, Brunnstrom, and Sherrington have found that the contralateral effects from an exercised upper extremity are most significant in the contralateral muscles that correspond to the agonist (called the co-agonists). Kruse and Matthews found that the nonexercised elbow flexor muscles had significant gains in strength and endurance after four weeks of training to the contralateral biceps brachialis muscles. Brunnstrom found that, in hemiplegic patients, flexion of the normal side of a one upper extremity evoked flexion of the hemiplegic side and that, likewise, extension evoked extension. Sherrington wrote that irradiation would innervate agonistic and not antagonistic muscles. This contrasts with Hellebrandt and associates' findings that during heavily resisted exercise to the wrist, the most significant effects in the contralateral limb were seen in the muscles corresponding to the antagonists (called the co-antagonists). Hellebrandt further suggests that when a person performs unilateral exercise against heavy resistance, postural readjustments involving the trunk musculature occur. These readjustments could be to stabilize the body. Russell found that during upper extremity PNF extensor patterns in normal subjects, most of the electrical activity in the unexercised limb tended to be produced in the stabilizing muscles. Panin and associates also proposed that the most contralateral electrical activity
from unilateral resisted exercise performed in straight planes is produced in the stabilizing musculature. The purpose of this study is to investigate whether contralateral musculature becomes active during resisted upper extremity PNF patterns and, if so, to examine the direction of activities.

**METHOD**

**Subjects**

Ten right-handed women between the ages of 22 and 34 volunteered for this study. Only female subjects were used so that the therapist could give maximal resistance throughout the range of movement. All subjects had prior training in PNF. None of them had a history of neurological or orthopedic disorders of the upper extremities or trunk.

**Equipment**

The electrical activity was recorded on a four-channel Grass model 7P polygraph with 7P1 driver amplifiers, 7P3 preamplifiers, and integrators.* A K- and-E Compensating Polar Planimeter† was used to quantify the integrated data, which were measured in EMG units.

**Procedure**

Two AC channels on the polygraph were calibrated for integrated data and two AC channels for raw data, so that both raw and integrated data were simultaneously recorded from each muscle. The raw data were recorded only to monitor artifact.

The PNF pattern chosen for the study was flexion, abduction, and external rotation with elbow straight (called the flexor component) and extension, adduction, and internal rotation with elbow straight (called the extensor component). This pattern was applied using the technique of slow reversals.

The muscles monitored in the left nonexercised upper extremity were the latissimus dorsi, pectoralis major (sternal portion), and infraspinatus. These muscles were differentially muscle tested to identify the muscle bellies. The muscle bellies were the site for electrode placement.

The skin resistance was decreased by cleaning the area, brushing it with emery paper, and applying electrode gel with a stencil brush.

Beckman silver-silver chloride electrodes‡ were then applied 1 cm apart over the muscle belly. All skin resistances were under 20,000 ohms. A ground electrode was placed on the dorsal head of the left ulna.

All subjects were supine on a plinth. A rolled towel was placed around the electrodes on the infraspinatus muscle to prevent them from coming in contact with the supporting surface. A double towel roll was placed under the subject's head to keep the head level with the thorax. The head was held in the midline position throughout the experiment. The nonexercised left upper extremity was placed in neutral at the side of the subject. The subject was instructed not to grip the edge of the plinth with the nonexercised limb. No other instructions were given. The PNF patterns were administered to the right upper extremity by a therapist with 12 years of experience in PNF and who was trained by Margaret Knott. The training and experience helped to ensure consistency in the application of resistance to the pattern.

The slow reversals and commands were reviewed with the subject on the right upper extremity before the actual testing. The pattern began with the shoulder in a position of adduction, extension, internal rotation with elbow extension and wrist and fingers flexion (Fig. 1). Upon the command of “open,” “turn,” and “lift up,” the subject moved into the flexor component. Upon the command of “squeeze,” “turn,” and “pull down,” the subject moved into the extensor component. Both flexor and extensor components were resisted in the right upper extremity five consecutive times while the electrical activity was monitored in two of the muscles of the left upper extremity. When the command of “open” or “squeeze” was heard by the person operating the polygraph, the time-event marker was pressed in order to differentiate the flexor and extensor components on the record. After a rest period of three minutes, another sequence of five slow reversals was resisted on the right upper extremity while the third muscle on the contralateral limb was monitored.

The recorded electrical activity for each monitored muscle in the nonexercised extremity was separated on the basis of whether it appeared during the flexor or extensor components in the right upper extremity.

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* Grass Instrument Co, 101 Old Colony Ave, Quincy, MA 02169.
† Model no. 620905, BL Makepeace Inc, 1266 Boylston St, Boston, MA 02215.
‡ Beckman Instruments, Inc, 599 N Ave, Wakefield, MA 01880.
Means, Standard Deviations, and \( t \) Values of Nonexercised Muscles

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Component of Slow Reversal of Non-exercised Extremity</th>
<th>( \bar{x} ) EMG (units/sec)</th>
<th>( s )</th>
<th>( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pectoralis Major</td>
<td>flexor</td>
<td>3.60</td>
<td>1.37</td>
<td>0.28</td>
</tr>
<tr>
<td>(sternal portion)</td>
<td>extensor</td>
<td>3.48</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>Latissimus Dorsi</td>
<td>flexor</td>
<td>4.00</td>
<td>2.94</td>
<td>2.45*</td>
</tr>
<tr>
<td></td>
<td>extensor</td>
<td>6.10</td>
<td>2.49</td>
<td></td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>flexor</td>
<td>5.62</td>
<td>2.57</td>
<td>3.82*</td>
</tr>
<tr>
<td></td>
<td>extensor</td>
<td>2.45</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>

* Statistically significant, \( p < .05 \).

The activity was then quantified with a planimeter and recorded in EMG units. The number of units representing flexor or extensor components was then divided by the total number of seconds, to the nearest quarter of a second, it took to complete either the flexor or extensor component on the right. Thus, the data were recorded in EMG units per second. The average in EMG units per second for five repetitions for each subject was calculated for each muscle.

A correlated \( t \) test\(^{14} \) was done to determine whether each nonexercised muscle fired significantly more (at the .05 level) when the exercised extremity was going into the flexor component or into the extensor component.

**RESULTS**

Electrical activity in the left nonexercised limb was present in all subjects during the administration of resistance to the PNF pattern of the right limb. The Table shows the mean and standard deviation of activity of each nonexercised muscle during the contralateral flexor and extensor components and the \( t \) values with nine degrees of freedom.

In the nonexercised left pectoralis major muscle, there was no significant difference between the amount of electrical activity occurring during resistance to the flexor component on the right and during resistance to the extensor component on the right. There was significantly more electrical activity in the nonexercised left infraspinatus muscle during resistance to the right flexor component than during resistance to the right extensor component. There was significantly more electrical activity in the nonexercised left latissimus dorsi muscle during resistance to the right extensor component than during resistance to the right flexor component (Fig. 2).

**DISCUSSION**

The sternal portion of the pectoralis major muscle acts as an agonist in the extensor component and as an antagonist in the flexor component of the pattern used in this study.\(^1\) Also, inasmuch as this muscle is located proximally, it may have stabilizing functions. There was no significant difference in the amount of electrical activity produced in the pectoralis major muscle of the left nonexercised extremity as the right arm moved into the flexor component as compared to the extensor component. This lack of significant difference suggests that neurologically based overflow is not specifically directed into the muscles corresponding to either the agonists or antagonists of the unexercised limb. If this muscle actively contracts for stabilization, it seems to contract equally in both the flexor and extensor components.

The infraspinatus muscle is an agonist in the flexor component as it externally rotates the arm and is an antagonist in the extensor component.\(^1\) The left infraspinatus muscle produced significantly more electrical activity during the flexor component of the right
upper extremity than during the extensor component. Thus, it may be concluded that it was acting as a co-agonist. This would support the theory of overflow effects being directed into the muscles corresponding to the agonistic muscle. If a muscle acts as a stabilizer, it may contract equally in the flexor and extensor components. If so, it is puzzling why the infraspinatus muscle would be more active as a stabilizer during the flexor component than during the extensor component.

The latissimus dorsi muscle is neither an agonist nor an antagonist in either the flexor or extensor components. If functions as an extensor, adductor, and medial rotator muscle of the shoulder and as a stabilizer. Significantly more electrical activity was seen in the left latissimus dorsi muscle during the extensor component of the right upper extremity than in the flexor component. This may disagree with the opinions of Knott and Voss, who did not cite the latissimus dorsi as an agonist or antagonist in either the flexor or extensor component. This study suggests the overflow may go from the flexion, adduction, and medial rotation movement in the exercised limb to the nonexercised latissimus dorsi muscle, which also has the functions of extension, adduction, and medial rotation. The nonexercised latissimus dorsi muscle would then be a co-agonist. Another possibility is that this muscle might also contribute to stabilizing the limb and trunk.

Another factor in the production of electrical activity may have been the tactile stimulation and pressure to the infraspinatus and latissimus dorsi muscles, inasmuch as both of them are in contact with the plinth. As the right limb underwent the flexor and extensor components, the position of the shoulder and trunk may have changed, thus rendering different surface areas in contact with the plinth and different amounts of pressure on the muscles. An increase in stimulation and pressure may have facilitated these muscles.

If a therapist is to use this pattern, he can now be aware of some of the possible effects in the contralateral limb. There is now some basis for selecting an exercise and predicting its contralateral effects. For example, if the goal is to activate the latissimus dorsi muscle in the nonexercised limb, the extensor component rather than the flexor component should perhaps be resisted. These results may be applicable to patients who are unable to exercise one of their upper extremities. But, inasmuch as this study was done on normal subjects, the results may not necessarily apply to patients. A therapist must be careful when applying these results to patients with orthopedic or neurologic disorders. The direction of contralateral effects must be observed for each patient and the treatment plan developed accordingly.

As a result of this experiment, suggestions for further studies have arisen. More muscles need to be tested to determine if and what generalizations can be made about these groups. More subjects need to be tested to ensure that these results are indeed a trend that pertains to the normal population. Additional PNF patterns and both isotonic and isometric techniques applied within the patterns need to be tested to determine the contralateral effects. Videotaping of subjects during the application of resistance to the patterns would be helpful to monitor the possible changes in body position that might occur for stabilization. Strength studies could be done to determine whether the repeated application of the PNF pattern increases strength in the contralateral nonexercised muscle. Once norms have been established on normal subjects, various patient populations can be studied to determine if contralateral effects differ in either amount or muscles activated.

CONCLUSION

The results of this study indicate that unexercised muscles do become active during resisted upper extremity PNF patterns in normal subjects when the contralateral limb undergoes an upper extremity PNF pattern. The production of electrical activity in the nonexercised limb appears to be as follows:

1) The sternal portion of the pectoralis major muscle appears to produce similar amounts of electrical activity during the application of resistance to the flexor and extensor components.

2) The infraspinatus muscle appears to produce more electrical activity during the application of resistance to the flexor than to the extensor component.

3) The latissimus dorsi muscle appears to produce more electrical activity during the application of resistance to the extensor than to the flexor component.

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